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Helicopter Aircrew Helmets and Head Injury: A Protective Effect

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USASC Technical Report 90-1

Helicopter Aircrew Helmets and Head Injury: A Protective Effect

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The effectiveness of the Army's SPH-4 flight helmet in reducing the severity of head injuries sustained during helicopter accidents was evaluated, using the accident data base at the U.S. Army Safety Center (USASC), Fort Rucker, Alabama. Analysis was restricted to severe (Class A) 1972-1988 accidents that were at least partially survivable, using USASC criteria. Occupants who were not wearing a protective helmet were significantly more likely to sustain severe and fatal head injuries than occupants wearing the SPH-4 (RR=3.8 and 6.3, respectively). Unhelmeted non-cockpit occupants faced higher risks (RR=5.3 and 7.5). All personnel regularly participating in helicopter flight, civilian or military, should be equipped with protective headgear.

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Helicopter Aircrew Helmets and Head Injury:

A Protective Effect

Introduction

On September 17, 1908, Lieutenant Thomas Selfridge tragically made aviation history by crashing with Orville Wright in a Wright Flyer.[1] Sustaining lethal head injuries, Selfridge became the first aircraft accident fatality. The ensuing (and first) aircraft accident investigation board recommended that head protection be developed and worn by aviators, a suggestion repeated hundreds of times by aviation safety experts over the past 82 years.[2]

Head injuries have repeatedly been shown to be the most common fatal injury in potentially survivable helicopter accidents.[3-6] Reasons for this predisposition include the forward locations of most occupants and of the engine/transmission assemblies, the high vertical G-forces, and the tendency for helicopters to spin and roll during the crash sequence.

In 1959, the APH-5 flight helmet was made widely available to U.S. Army aviators, and within 4 years a significant reduction in the number of severe head injuries was reported.[3] Introduced in 1970, the SPH-4 flight helmet (figure 1) is considered an essential piece of life-support equipment in modern Army aviation.[7] Today, throughout both fixed-wing and rotary-wing military aviation, flight helmets are accepted as standard life-support equipment.

However, the civilian rotary-wing aircraft community has been slow to embrace flight helmets and other protective life-support equipment. In 1987, published estimates of helmet use in civilian emergency medical services (EMS) aviation programs in the United States ranged from 6.5 percent to 10 percent, while fire-retardant uniforms were required by approximately 15 percent to 24 percent.[8, 9] In 1989, Kruppa reported that EMS programs' use of helmets and fire-retardant uniforms had increased to only 13 percent and 29 percent, respectively.[10]

Reasons for low utilization of protective flight helmets in the EMS aviation environment include a lack of awareness in the civilian helicopter community of the potential safety benefits afforded by flight helmet use. This is reflected in a recent exchange of letters in the *AeroMedical Journal*,[11] in which a writer responded, "There is little actual scientific data to substantiate the mandatory use of helmets as safety equipment. Clearly, helmets provide extra protection, but does this extra measure of protection make a real difference in survival at the critical moment?"

Figure 1. SPH-4 flight helmet (Official U.S. Army photograph)

Data from all Army aviation accidents since 1972 are entered into the Army Safety Management Information System (ASMIS) data base, maintained at the U.S. Army Safety Center (USASC), Fort Rucker, Alabama. Since the Army is the major user of rotary-wing aircraft in the western world, this data base is a valuable resource, containing information from approximately 70,000 Army

aviation accidents. Using the ASMIS data base, this study assesses the effect of the Army's current flight helmet, the SPH-4, on the risk of head injury in helicopter crashes over the past 18 years.

Methods

All Army Class A helicopter accidents (using criteria in effect at the time of the accident) occurring from 1 January 1972 to 31 December 1988 were eligible for inclusion in this study. Class A accidents are currently defined as accidents in which the property cost is $1,000,000 or greater, or there is total loss of an aircraft, or there is a fatality or permanent total disability.[12]

Analysis was restricted to accidents determined to be at least partially survivable (termed "survivable accidents" in this report) by the accident investigation board. An accident is considered partially survivable if any of the potentially occupied areas of the aircraft experienced crash forces that were within the limits of human tolerance, and if the structural integrity of that occupiable space was sufficiently maintained to permit occupant survival.[13]

The "exposed" subjects for this study were defined as occupants who were not wearing any protective helmet during Class A survivable helicopter crashes occurring during the study period. The "unexposed" comparison group included all occupants who were wearing SPH-4 helmets during Class A survivable helicopter crashes. These two samples were compared with regard to head injury patterns and severity, cause of death (COD), and seating location within the aircraft.

Injuries coded by the USASC Surgeon as major, critical, or fatal were combined and termed "severe" in this analysis. Only injuries to areas of the head that are covered by the flight helmet were counted when comparing injury patterns. This restriction excluded injuries to the face and jaw area. However, in the COD analysis, since the precise anatomical region is not usually specified, any "head injury" listed as a COD was included.

A measure of relative effect, the risk ratio (relative risk), was used to indicate the strength of certain associations (risk in group A/risk in group B = risk ratio).[14] A risk ratio of 1 indicates no difference in risk between two groups; a value of >1 indicates a greater risk in the first group, etc. Confidence intervals (CI) were calculated, using a logarithmic transformation, in order to assess the significance of this measure.[15] A CI for a ratio is significant at the specified level (i.e., 95% or 99%) if the CI does not contain the value "one."

Results

The ASMIS data base revealed that 60,372 helicopter accidents occurred during the study period. Of these, 754 were Class A accidents, of which 595 were determined by accident boards to be survivable. There were 104 individuals who met the criteria for inclusion

Table 1. Sample composition by location and duty

	Unhelmeted sample	SPH-4 sample
Cockpit crew	15	982
Non-cockpit crew	89	401
Engineer	(0)	(12)
Gunner	(4)	(29)
Crew chief	(0)	(143)
Passengers	(83)	(157)
Other	(2)	(60)
Total	104	1,383
Aircraft involved	52	546

Table 2. Head injury severity and cause of death

	Unhelmeted sample (n=104)		SPH-4 sample (n=1383)			
	#	Rate [a]	#	Rate [a]	RR	CI
<u>Head injuries</u>						
Severe	17	16.3	60	4.3	3.77	2.0, 7.2 [d]
Fatal	8 [b]	7.7	17 [c]	1.2	6.26	2.2, 18.2 [d]
<u>Cause of death</u>						
Head injury	7	6.7	42	3.0	2.22	1.02, 4.8 [e]

[a] Per 100 aircraft occupants
[b] Occurring in 6 fatally injured individuals
[c] Occurring in 11 fatally injured individuals
[d] 99% Confidence Interval
[e] 95% Confidence Interval

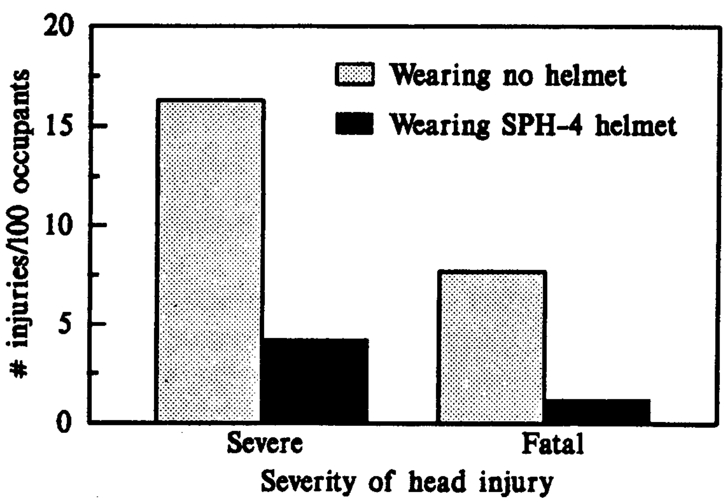

Figure 2. Helmet use and head injury

Table 3. Causes of death in survivable Class A helicopter accidents

Cause	#	(%)
Head injuries	66	(45.8)
Injuries, multiple, extreme	35	(24.3)
Drowning	12	(8.3)
Miscellaneous	12	(8.3)
Hemorrhage/shock	11	(7.6)
Heart/great vessel trauma	8	(5.6)

Note: Includes all occupants of Class A helicopter accidents occurring between 1 January 1972 and 31 December 1988.

in the unhelmeted sample (exposed), and 1,383 people met the criteria for the SPH-4 sample (unexposed) (table 1). There was no significant difference between the samples with regard to aircraft vertical speed at the time of impact, a measure of crash severity (t-test, 95%CI –471.6, 182.8).

The comparison of head-injury severity between these samples is shown in table 2. Clearly, the unhelmeted occupants were at a significantly greater risk of severe and fatal head injury than those wearing SPH-4 helmets (figure 2). Since each occupant could contribute more than one injury to the analysis, the risk of an occupant receiving any fatal head injury was determined. In the unhelmeted and SPH-4 samples, there were 6 and 11 occupants with fatal head injuries, respectively (RR= 7.25, 99%CI 2.1, 25.6).

The causes of death listed for fatalities in survivable accidents during the study period are presented in table 3. The risk of having "head injury" listed as the COD was significantly greater for the unhelmeted occupants compared to those wearing the SPH-4 (table 2).

To assess any possible confounding effect due to occupant location in the aircraft, a further comparison was made of injury severity

Table 4. Head injury severity in non-cockpit occupants

	Unhelmeted sample (n=89)		SPH-4 sample (n=401)			
	#	Rate [a]	#	Rate [a]	RR	CI [b]
Head Injuries						
Severe	14	15.7	12	2.9	5.26	1.5, 11.5
Fatal	5 [c]	5.6	3 [c]	0.7	7.51	1.2, 47.5

[a] Per 100 aircraft occupants
[b] 99% Confidence Interval
[c] Occurring in 3 fatally injured individuals

between the unhelmeted and SPH-4 groups, considering only occupants not located in the cockpit (table 4). The protective effect of the SPH-4 is even more apparent for these individuals. The ASMIS data base was further queried regarding restraint use in this subgroup, since the head injuries in the unhelmeted sample might have been due to non-use of lap-belt restraints by passengers. Seven of the 9 unhelmeted non-cockpit occupants sustaining severe head injuries were wearing a lap-belt restraint, compared to 8 of the 10 similarly injured SPH-4 wearers (one-tailed Fisher's Exact Test, p= 0.667).

Discussion

This analysis has clearly demonstrated that the Army's standard flight helmet, the SPH-4, provides significant protection from serious head injury. In the helicopter crashes studied, fatal head injuries were six times more common in unhelmeted occupants than in those wearing the SPH-4 (table 2). Severe head injuries were almost four times more common in the unhelmeted group. Further, unhelmeted occupants were more than twice as likely to have "head injury" listed as the cause of death than were the SPH-4 wearers. All of these findings are statistically significant.

Helicopter passengers and crewmembers riding in the rear of the aircraft receive an even greater protective effect from the SPH-4 (table 4). This is an important finding, since most civilian flight nurses and medics are not provided flight helmets.[8-10] Even in military aviation, helicopter passengers frequently do not wear protective headgear. Although soldiers being transported by helicopter often wear a combat helmet, data regarding use of non-flight helmets are not entered in the ASMIS data base. Therefore, this aspect could not be investigated.

These findings support the results of human cadaver research showing the benefit of helmet use,[16] as well as the results of computer modeling of head/neck injuries in helmeted and unhelmeted motorcycle accident victims.[17] The present study provides even stronger evidence of protection from head injury than previously published research based on an older flight helmet (the APH-5). The 1961 report, *Army Aviation Accident Experience,* found that fatal head injuries were 2.4 times more common among unhelmeted occupants in helicopter accidents, compared to helmet-wearing occupants, and credited the APH-5 helmet with saving 265 lives between 1 July 1957 and 31 December 1960.[3] Although the present study does not estimate a number of lives saved, the measures of association (relative risks) are stronger and achieve higher levels of statistical significance compared to those presented in the 1961 report.

Reasons cited for not using flight helmets in EMS aviation include cost, the patient's psychological well-being, and the lack of evidence of benefit.[10] Concerns about public relations and the patient's emotional state, while well-intended, ignore that—

☐ A regular aircrewmember's level of exposure to the hazards of the aviation environment is far greater than the patient's.

☐ If there should be a crash, the crew will provide better service to the passengers and/or patients by remaining conscious and assisting with emergency egress than by sustaining severe injuries to their own unhelmeted heads.

This study shows that by wearing a good protective helmet, the medical crewmember can reduce his/her chances of sustaining a severe head injury in a serious but potentially survivable crash by a factor of five. Therefore, all personnel regularly participating in helicopter flight, civilian or military, should be equipped with protective headgear.

To obtain maximum benefit from a protective helmet in helicopter aviation, several factors must be considered. The helmet must distribute impact forces, absorb energy, and resist penetration and fracture by contact with unyielding surfaces.[18] Helmet retention failure has been associated with both the number and severity of head injuries sustained during helicopter accidents.[19] To ensure helmet retention during the crash sequence, the helmet must be individually fitted and properly adjusted by trained personnel.[20] In addition to impact and fire protection, the flight helmet provides hearing protection, facilitates communication, and serves as a platform for helmet-mounted displays or night vision goggles.[7]

Summary

The SPH-4 flight helmet significantly reduces the likelihood of severe and fatal head injury in occupants of serious but survivable helicopter accidents. This paper provides additional evidence supporting the acquisition of protective helmets for all personnel who regularly fly in helicopters.

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